IN THE SPECIFICATION:

Please amend the text appearing above the title as follows:

~~SPECIFICATION~~TITLE

DEPLOYABLE TRUSS HAVING SECOND ORDER AUGMENTATION

Please amend paragraph **[0003]** as follows:

[0003] One specific type of a shell boom, referred to as a STEM in the space industry, for Storable Tubular Extendable Member, is disclosed in U.S. Patent No. 3,144,104. A STEM, which typically incorporates a coilable thin metal strip, such as shown in the figures of U.S. Patent No. 3,144,104, are precurved and form a cylindrical shell when deploying. These devices have found use in low load applications such as antennas and gravity gradient stabilization booms due to their compactness.

Please amend paragraph **[0004]** as follows:

[0004] In general, a cylindrical shell, or tube, is a simple and mass efficient structure. However, STEMs have strength limitations since the deployed metal strip does not form a closed section. Multiple overlapped STEMs, such as those shown in various figures of U.S. Patent No. 3,434,674 and methods of interlocking the overlapped section(s) (see, e.g., ~~figure~~ Fig. 8 of U.S. Patent No. 3,144,104) have been pursued to increase strength.

Please amend paragraph **[0008]** as follows:

[0008] A lattice boom typically comprises a number of axially arranged structural elements, which are frequently referred to as longerons. Typically, the longerons are braced in a repeating fashion at intervals often referred to as bays. The longerons are typically rods, or sometimes tubes, and are braced at close intervals to prevent slenderness concerns from arising at the bay level. Structural members used to perform the bracing function are often referred to as battens. Diagonals, or as also sometimes referred to as stays or ~~cross members,~~ cross-members, are typically provided along each face of the bays to add structural rigidity. Diagonals, for

example, may be in the form of crossing cables, each bearing tension only, or one or more rigid structural members capable of bearing both tension and compression.

Please amend paragraph **[0009]** as follows:

[0009] One bay of a typical collapsible four-sided lattice structure is shown in ~~Figure~~ Fig. 1 of U.S. Patent No. 5,016,418, issuing to Rhodes ~~et al,~~ et al., the disclosure of which is hereby incorporated by reference. Each bay, or structural unit, is constructed of structural members connected with hinged and fixed connections at connection nodes in each corner of the bay. Diagonal members along each face of the bay provide structural rigidity and are equipped with mid-length, ~~self locking~~ self-locking hinges to allow the structure to collapse. Many other clever schemes for the articulated folding of repeating bay booms, or truss structures, have been arranged.

Please amend paragraph **[0010]** as follows:

[0010] For example, U.S. Patent No. 4,475,323, issuing to Schwartzberg et al., which is incorporated herein by reference, discloses a deployable box truss hoop. U.S. Patent No. 4,557,097 to Mikulas, Jr. et al., which is also hereby incorporated by reference, discloses a sequentially deployable, maneuverable tetrahedral beam truss structure. U.S. Patent No. 4,569,176 to Hedgepeth et al., hereby incorporated by reference, discloses a deployable lattice column having three sides and rigid diagonal members formed of rigid elements. U.S. Patent No. 4,599,832 to Benton et al. ("Benton"), hereby incorporated by reference, discloses an extendible structure that can be collapsed to a shorter length and extended to a longer length. The extendible structure disclosed in Benton comprises a pair of station members interconnected by at least three longeron members. Each longeron member has two longeron elements that are pivoted together so they can fold toward one another or be aligned to form a column. Each longeron element is pivoted to a respective station member. Preloaded diagonal cable stays rigidify the structure when extended, being opposed by buckling springs (or Euler columns) that exert a radially outward resultant force in each bay at the folding point of each longeron member.

The articulated lattice configuration disclosed in Benton was used to deploy the solar arrays on the international space station.

Please amend paragraph **[0011]** as follows:

[0011] Another example of a repeating bay boom or truss structure comprised of collapsible bays formed from articulating members is provided in U.S. Patent No. 4,677,803 to Mikulas, Jr. et al. ("Mikulas"), which is hereby incorporated by reference. The Mikulas patent discloses a deployable geodesic truss structure. The Mikulas geodesic truss structure includes a series of bays, each bay having sets of battens connected by longitudinal ~~cross members which~~ cross-members that give the bay its axial and torsional stiffness. The ~~cross members~~ cross-members are hinged at their ~~mid point~~ mid-point by a joint so that the ~~cross members~~ cross-members are foldable for deployment or collapsing. Hinged longerons may also be provided to connect the sets of battens and to collapse for stowing with the rest of the truss structure. U.S. Patent No. 5,267,424, issuing to Douglas, and which is hereby incorporated by reference, discloses a ~~bay, or~~ "bay" or, as referred to in the ~~patent a module,~~ patent, a "module" for forming an articulated stowable and deployable mast. Further, U.S. Patent No. 6,076,770 to Nygren et al., which is hereby incorporated by reference, discloses a folding truss that comprises a number of articulating column members.

Please amend paragraph **[0013]** as follows:

[0013] An alternative lattice truss structure with joint-less longerons, and hence higher compaction and lower risk, is the coilable lattice truss boom. Numerous adaptations of this often employed structure exist. For example, U.S. Patent No. 4,918,884 to Okazaki et al., which is hereby incorporated by reference, discloses an example of a coilable lattice truss that employs a plurality of radial spacers to define bays along a plurality of longerons arranged parallel to one another and attached to a pair of endplates. A pair of diagonal cords are stretched between adjacent radial spacers, between one of the end plates and the uppermost radial spacer and between the other of the end plates and the lowest radial spacer, respectively. A means is attached to one of the paired diagonal cords stretched between one of the end plates and the

uppermost or lowest radial spacer to apply a predetermined tension to the diagonal cord. To collapse the truss structure, the longerons are elastically buckled between the radial spacers so as to coil the longerons between the endplates. The transforming of the longerons, and longitudinal position of the radial spacer located at one end of the structure, can be restrained by a means of applying overall axial tension while the structure is being deployed or collapsed. Other examples of coilable lattice truss booms are described in U.S. Patent No. 3,486,279 to Webb for a deployable lattice column; U.S. Patent No. 4,334,391 to Hedgepeth et al. for a redundant deployable lattice column; U.S. Patent No. 4,532,742 to Miura for an extendible structure; and United States Patent No. 5,094,046 to Preiswerk for a deployable mast.

Please amend paragraph **[0014]** as follows:

[0014] Because the longerons in coilable lattice booms are highly strained when coiled for stowage, the material of choice for such longerons is typically a flexible glass fiber composite, such as an S2 glass fiber composite. As a result, in typical performance regimes, current coilable truss designs possess far in excess of a desirable amount of stowed strain energy, resulting in excessive push forces. ~~This in turn~~ This, in turn, requires the use of equipment sized to handle the resulting push force while the truss is in the stowed configuration, as well as when it is being deployed or collapsed. The required additional mass of the deployment mechanism to safely handle the push force of current coilable trusses adds parasitic mass and limits their overall mass efficiency.

Please amend paragraph **[0016]** as follows:

[0016] High-performance graphite fiber composites potentially provide a huge gain in stiffness to weight capability over other available material options, such as flexible glass fiber composites, such as S2 glass fiber composites, and possess very low coefficients of thermal expansion. These are critical traits for future stable gossamer structures. ~~But graphite~~ Graphite fiber composite materials have limited applicability in known coilable lattice structures because graphite fiber composite materials have strain capabilities typically two to three times lower than glass fiber composite materials. Therefore, only much smaller, and hence weaker, longer rods

can withstand the curvature encountered during stowage. The local buckling strength of a longeron is a function of the rod inertia, which is proportional to the diameter to the fourth power. This limits the utility of graphite composite longerons in currently practiced coilable lattice structure because the maximum diameter graphite longeron (approximately 1/3 that of an S2 glass fiber longeron) that can be used in known coilable structures would possess up to approximately 80 times less inertia. Even granting that a graphite rod is likely to be as much as 4 times stiffer in extensional modulus than a S2 rod, the buckling strength will still be 20 times lower than the heritage material (assuming equal column length).

Please amend paragraph **[0018]** as follows:

[0018] In recent years, numerous inflatable systems, which can use graphite fiber composites, have been under intense development in the hope that such systems would achieve a leap in mass and packaging efficiency, allowing ever larger systems to be packaged within the constraints of affordable launch systems. ~~But, in~~ In practice, it has been difficult to achieve the structural efficiency of an articulated structure with an inflatable system due to mass overhead in non-structural systems such as: bladder materials, thermal barrier layers, node fittings, and inflation equipment and sequencing mechanisms. Inflatable systems are also plagued with structural inefficiencies inherent with the use of folding or rolling collapsed composite tubes. To allow the folding or rolling of collapsed composite tubes, the graphite material must be capable of withstanding high strain, requiring a reduction in fiber stiffness, ~~fiber to matrix~~ fiber-to-matrix volume ratios, and/or the use of a woven fabric, which reduces the effective stiffness.

Please amend paragraph **[0019]** as follows:

[0019] High performance tubular composite systems require composite tubes with maximum structural stiffness and high stability. Composite tubes achieve maximum structural efficiency when constructed from layered-fibers mostly oriented nearly axially to the lengthwise direction of the tube. The most stable composite tube lattice structure would be joined by bonding at composite nodes. However, such systems are not generally collapsible, although

some have been proposed. One such proposed system is described in U.S. Patent No. 6,321,503 to Warren. The mass efficiency of this system is high and the structure is stable, but the compaction ratio is poor. Allowing the tubes to be partially flattened, as described in U.S. Patent No. 6,343,442 to Marks, increases the compaction, but it is still not satisfactory.

Please amend paragraph **[0021]** as follows:

[0021] A need, therefore, exists for deployable truss structures that improve on one or more of the above noted deficiencies of currently known deployable truss structures, yet maintain the reliable deployment characteristics of articulated and coilable lattice structures. ~~Preferably~~ Preferably, such truss structures would also improve on at least one of the attributes of mass efficiency, stowage volume, and thermal stability, and preferably all three. A need also exists for such structures that can make practical use of high-performance graphite fiber elements. A need further exists for column members that will enable improved deployable truss structures to be built.

Please amend paragraph **[0036]** as follows:

[0036] Figs. 2A-2D are a series of schematic illustrations of ~~cross sections~~ cross-sections of different column arrangements.

Please amend paragraph **[0054]** as follows:

[0054] Fig. 1C illustrates two bays 61 of a deployable boom truss 60 according to one embodiment of the present invention. As discussed more fully below, deployable boom truss 60 may be an articulating truss structure or a coilable truss structure. Deployable boom truss 60 comprises a plurality of column members 64 connected at their ends at node joints 65. Two crossing diagonal cable stays 67 are provided on each face of bays 61 to add additional structural rigidity to deployable boom truss 60. In the present embodiment, the column members 64 forming the longeron elements of bays 61 comprise column assemblies 66. Each column assembly 66 comprises three strut members 68 that are connected to each other at a first end 70 of the column ~~assembly~~ assembly 66 and at a second end 72 of the column assembly. As

illustrated, strut members 68 are preferably symmetrically arranged about the centerline of their respective column assembly 66. Each column assembly 66 of the present embodiment also includes a spacer 74 connecting the strut members of the column ~~assembly~~ assembly 66 at a location between the first and second ends 70, 72 of the column ~~assembly,~~ assembly 66, and preferably at the mid-point between the two ends 70, 72. Spacers 74 brace the strut members 68 of each column ~~assembly~~ assembly 66 so that they are mutually stabilized and symmetrically spaced from the centerline of their respective column ~~assembly.~~ assembly 66. To fit size, and mass, at the node joints 65, however, the strut members 68 are preferably tapered toward the first and second ends 70, 72 of the column assemblies 66.

Please amend paragraph **[0055]** as follows:

[0055] By locating spacers 74 in the middle of column assemblies 66, as illustrated, the effective buckling length of each strut ~~member~~ member 68 is effectively cut in half while the effective diameter, and hence moment of ~~inertia~~ inertia, of the column assembly 66 is increased. Indeed, by spacing strut members 68 about the centerline of column assemblies 66 a distance equal to the radius of columns 44 shown in Fig. 1B, the section inertia of column assemblies 66 will be comparable to that of columns 44. As a result, deployable boom truss 60 of the present invention can provide comparable bending stiffness to that of boom truss 42, yet with substantially less mass.

Please amend paragraph **[0056]** as follows:

[0056] The deployable boom truss 60 shown in Fig. 1C is considered to exhibit ~~second-order~~ second-order augmentation because the use of column assemblies 66 comprising a plurality of discrete strut members 68, such as rods or tubes, as column members 64 in the truss provides, from a hierarchical standpoint, a second level or order of augmentation to truss 60 in that they provide multiple load paths.

Please amend paragraph **[0057]** as follows:

[0057] While the column assemblies 66 of the present embodiment include three strut members 68 and one spacer 74, in other embodiments it may be desirable to include more than three strut members 68 or more than one spacer 74. Furthermore, column assemblies 66 could also be substituted for the column members 64 corresponding to the battens in deployable boom truss 60. ~~And, while~~ While deployable boom truss 60 of the present embodiment employs crossing diagonal cable ~~stays~~ stays 56 to add structural rigidity, in other embodiments a single column assembly according to the present invention could be used as a diagonal member.

Please amend paragraph **[0058]** as follows:

[0058] Figs. ~~2A-D~~ 2A-2D are used to further qualitatively illustrate the structural efficiency of using column assemblies according to the present invention as column members in a deployable truss. Consider a thin-walled composite tube 80, as shown in Fig. 2A. Assume that this ~~thin-walled~~ thin-walled composite tube has the necessary ~~cross sectional~~ cross-sectional area, section inertia, and minimum wall thickness to satisfy the stiffness and strength requirements of a given application when used as a column member in a deployable truss. Fig. 2B shows a solid rod 82 with the same ~~cross sectional~~ cross-sectional area (not shown to scale in figures) of the composite tube 80. The solid rod 82 would have the same axial stiffness and strength in tension as tube 80 since they have the same ~~cross-sectional~~ cross-sectional area, but would buckle in compression at a much lower load since the section inertia of the solid rod 82 is much lower than the section inertia of the tube 80. The ~~cross sectional~~ cross-sectional area of tube 80 could similarly be separated, or stranded, into a number of smaller diameter rods or tubes. For example, Fig. 2C shows the ~~cross sectional~~ cross-sectional area of tube 80 being divided equally into three solid rods 84. A column formed from the three rods 84 would collectively duplicate the axial stiffness and strength in tension of the original tube 80 shown in Fig. 2A but not its strength in compression, because the section inertia of the three solid rods 84 as arranged in Fig. 2C is much lower than the section inertia of tube 80. Further, the section inertia of the rods 84, as arranged in Fig. 2C, may also be less than the section inertia of the single solid rod 82. But, if, as shown in Fig. 2D, rods 84 are mutually stabilized and equally

spaced from the centroid by a spacer so as to lie on a circle 86 equal to the diameter of the original tube 80 as shown in Fig. 2D, the section inertia of the configuration will approximate the section inertia of the original tube 80. Thus, dividing the ~~cross sectional~~ cross-sectional area of a tube into rods, and spacing those rods equally on a circle equal to the diameter of the original tube will approximate the ~~cross sectional~~ cross-sectional area and section inertia of the original tube. However, by spacing those rods evenly on a circle of even greater diameter than the diameter of the original tube would make the section inertia of the system of rods greater than the section inertia of the original tube. Similarly, a series of spaced tubes could be used instead of a series of rods to replace the original single tube.

Please amend paragraph **[0059]** as follows:

[0059] The foregoing qualitative analysis illustrates that the column assemblies 66 of the present invention allow the same amount of material to be used at a larger diameter, as in a ~~mass optimum,~~ mass-optimum, but often unrealistically thin, shell column member, thus permitting column members to be constructed with safe slenderness ratios and with a minimal amount of material.

Please amend paragraph **[0061]** as follows:

[0061] Deployable truss 90 is a modified version of the deployable truss described in U.S. Patent No. 5,267,424 (referred to hereinafter as "the '424 patent"), which is hereby incorporated by reference. Deployable truss 90 has been modified from the truss described in the '424 patent in that column assemblies 66 according to the present invention have been employed for the longerons 96 and the battens 98 in the truss. However, deployable truss 90 is otherwise deployed in the same manner as the truss described in the '424 patent.

Please amend paragraph **[0063]** as follows:

[0063] Fig. 4 schematically illustrates various embodiments of column assemblies according to the present invention. Column assemblies 120, 130, 140, and 150 illustrate column assemblies comprising curved continuous strut members 68 with increasing levels of bracing by

spacers 74. Column assemblies 160, 170, 180, and 190 illustrate column assemblies having increasing bracing and employing straight strut elements 192 between bracing points to form strut members 68. Segmenting strut members 68 into straight strut elements 192 between intermediate bracing points provided by spacers 74, as illustrated in column assemblies 160, 170, 180, and 190, will maximize strength and stiffness of the strut members 68. This is because smaller eccentricity of the strut members 68 from an imaginary line connecting spacing positions should increase buckling strength and stiffness of the strut members 68. On the other hand, forming strut members 68 from one section of, for example, a continuous fiber reinforced composite rod or tube that is curved during assembly allows more economical construction of the column assemblies from longer lengths of material. As further illustrated in Fig. 4, the strut members 68 of a column assembly may be braced at an arbitrary number of intermediate locations. However, there is a ~~trade off~~ trade-off between increased bracing and increased mass. As a result, from a mass optimization standpoint there may be a diminishing value of return as the number of bracing points increase. It should also be noted that in certain implementations of the present invention, which are discussed more fully below, it may be desirable not to provide any bracing.

Please amend paragraph **[0064]** as follows:

[0064] As noted above, eccentricity of the strut ~~members~~ members 68 from an imaginary line connecting fixed spacing points of the strut ~~members~~ members 68 affects their buckling resistance. Generally, a smaller level of eccentricity results in increased buckling strength and stiffness. As best seen from Fig. 5, if strut members are formed from continuous lengths of material, the angle held when the strut members are bonded into a node fitting can be optimized to minimize eccentricity. Fig. 5 schematically illustrates two column assemblies 200 and 220 according to the present invention. Two strut members 202, 206 of column assembly 200 are shown, and two strut members 222, 226 of column assembly 220 are shown. Strut members 202, 206, 222, and 226 are formed from continuous curved members. In the lower column assembly 200, strut members 202, 206 are permitted to naturally curve from fixed bracing points 214, 216 to the end of the column assembly with a pin-ended connection. As a

result, the angle between the strut members 202, 206 and centerline 210, which coincides with the line of action of the buckling load on the column assembly, is fairly large. This in turn results in strut members 202, 206 having some level of eccentricity represented as A in Fig. 5. Moreover, all of the ~~eccentricity~~ eccentricity A of strut members 202, 206 falls outside of imaginary line 209. In the upper column assembly 220, the angle formed between the strut members 222 and 226 at the connection and the centerline 230, which also coincides with the line of action of the buckling lode on the column ~~assembly,~~ assembly 220, has been optimized to reduce eccentricity of strut members 222, 226 from imaginary line 229 connecting bracing points 234, 236 and the end of the column assembly. The angle is reduced by connecting strut members 222 and 226 in a fixed end condition and such that the tangent of strut members 222 and 226 at the fixed connection approaches or even aligns with centerline 230. As seen from Fig. 5, by reducing the angle that strut members 222 and 226 approach the end of column assembly 220, the maximum amount of eccentricity of the strut members is reduced by 1/2 to A/2. Furthermore, the eccentricity of strut members 222, 226 is now more balanced on both sides of imaginary line 229. The angle held by strut members ~~222,~~ 222 and 226 may be set based on the angle at which the strut members 222, 226 are bonded into the node fittings (not shown). ~~Figure~~ Fig. 5 illustrates merely the practical limiting cases on the variability in eccentricity for a column assembly with a single spacer. Proper angle constraints for structural optimization of columns with other numbers of spacers would be evident to those skilled in the art from the above discussion.

Please amend paragraph **[0068]** as follows:

[0068] The nesting height of a large number of such spacers is the total height of the spacers stacked on top of each other divided by the number of spacers. For example, the stack height of the spacers 270, 280 in Fig. 6A is shown as distance 285 and is approximately the distance between strut member 264 of spacer 280 and strut member 250 of spacer 270. A smaller nesting height generally results in an increase in storage compaction. As shown in Fig. 6A, leg 276 of spacer 270 contacts spacer 280 at central strut member 266 when spacers 270 and 280 are nested. Figs. ~~6A-D~~ 6A-6D collectively demonstrate that spacer designs allowing a

central strut member limits the minimum achievable nesting height when stowing multiple spacers of an identical design. Because high compaction is an important goal of all deployable space structures, foregoing a central strand would be advantageous when employing fixed spacers in the column assemblies according to the present invention to improve nesting.

Please amend paragraph **[0070]** as follows:

[0070] In connection with Figs. 2A-2D discussed earlier it was shown that the section inertia and ~~cross sectional~~ cross-sectional area of a tube, Fig. 2A, can be approximated by three rods 84 separated such that they are equidistant and lying along a diameter equal to the diameter of the original tube as shown in Fig. 2D. The ~~rods~~ rods 84 of Fig. 2D are positioned similarly to the strut members shown in Fig. 7 such that strut members braced by each spacer 300, 320 of Fig. 7 approximate the section inertia and ~~cross sectional~~ cross-sectional area of an equivalent tube. The equivalent tube would be of the same ~~cross sectional~~ cross-sectional area as the sum of the area of the three strut members (e.g., strut members 302, 304, 306) with the wall of the tube tracing a path through a perpendicular ~~cross section~~ cross-section of the three strut members 302, 304, 306. Fig. 7 illustrates that by employing fixed spacers in the column assemblies according to the present invention the ~~cross sectional~~ cross-sectional area and section inertia of two tubes can be nested into a space that approximates the height of only a single tube. Specifically, the distance 334 in Fig. 7, the nesting height of the two spacers, is only slightly more than the diameter of the equivalent tube--i.e., the tube with the same ~~cross sectional~~ cross-sectional area and section inertia of the three strut members 302, 304, 306 separated by spacer 300 or the three strut members 322, 324, 326 separated by spacer 320. It will be appreciated that the savings in stowage volume will be significantly multiplied as additional column assemblies employing the V-shaped spacer design are nested together.

Please amend paragraph **[0071]** as follows:

[0071] While the properties, ~~cross sectional~~ cross-sectional area and section inertia, of a tubular section can be duplicated by stranding—placing members equidistant on a circle equal to the diameter of the original tube—stranding can produce a structure with even greater section

inertia than the original tube if the members are positioned equidistant on a circle greater than the diameter of the original tube. This may be desirable, because in a first-order deployable truss the tubular elements could well be approaching slenderness ratio limits to optimize packing. Using column assemblies with larger diameters also allows a truss structure to be designed with longer bays. This allows an advantageous tradeoff in overall packing and cost, given that fewer elements are needed for a given overall length structure. An example of such a truss structure is illustrated in Figs. 8A-8D.

Please amend paragraph **[0072]** as follows:

[0072] ~~Figures~~ Figs. 8A-8D illustrate another embodiment of a deployable truss structure 360 employing second order augmentation according to the present invention. Truss structure 360 may be used to deploy a number of panels 366 and panels 368. Panels 366 may, for example, be SAR panels, and panels 368 may, for example, be solar panels, or vice versa. ~~Figure~~ Fig. 8A shows the deployable truss structure 360 in a stowed position and situated on satellite 350. In this stowed position the truss structure 360 along with panels 366 and 368 could be sized to fit within the cargo space of a standard launch vehicle, such as a Delta IV - M or Delta IV - Heavy rocket.

Please amend paragraph **[0073]** as follows:

[0073] ~~Figure~~ Fig. 8B shows the truss structure 360 during deployment wherein the panels 366 and supporting column members are deployed. The panels 366, 368 deploy automatically with bays 370 of the truss ~~structure.~~ structure 360. Bays 370 unfold at node joints 400 providing for articulation of the ~~structure.~~ truss structure 360. The other elements of the truss ~~structure~~ structure 360 are seen more clearly in Fig. 8C where a portion of the truss structure 360 is shown during deployment, and Fig. 8D where a portion of the truss ~~structure~~ structure 360 is shown fully deployed. The sides of each ~~bay~~ bay 370 comprise column assemblies 384 acting as longeron members, and column assemblies 380 acting as diagonal members in the truss ~~structure.~~ structure 360. Each face of a bay 370 also includes two column members 386 acting as battens. Column assemblies 380 and 384 each comprise a plurality of

strut members connected to each other at the ends of ~~the~~ each column assembly 380, 384. Further, in the present embodiment, each column assembly 380, 384 is provided with three V-shaped spacers 390, like the ones illustrated in Fig. 7, to space the struts away from the centerline of the column assemblies 380, 384.

Please amend paragraph **[0075]** as follows:

[0075] The column assemblies, and hence the truss structures, according to the present invention can be stowed more compactly if the strut members are spaced with a deployable spacer instead of a fixed spacer. Because it has been analytically found that the stiffness of the column assemblies is relatively insensitive to spreader stiffness and that the energy required to spread the strut members is relatively small, a wide variety of deployable spacer designs are possible. Various deployable spacers for separating four strut members and their corresponding configuration for strut member deployment are illustrated in Figs. 9A-9F. The strut members are separated by a strained hoop in Fig. 9A, a hinged ~~cross brace~~ cross-brace in Fig. 9B, a sprung frame in Fig. 9C, carpenter tape strips in Fig. 9D, an inflatable sphere in Fig. 9E, and inflatable bellows in Fig. 9F. The methods used to spread the strut members can thus, for example, include the use of strain energy, elastic memory composites, and inflation gas. A chart listing some of the pros and cons of the different methods to spread the rods is included in Table 1, below.

Please amend paragraph **[0077]** as follows:

[0077] Reviewing the various deployable spacers in more detail, Fig. 9A shows a strained hoop 450 separating strut members 452, 454, 456, and 458. Fig. 9B shows a hinged cross-brace 460 separating strut members 462, 464, 466, and 468. Fig. 9C shows a sprung frame 470 separating strut members 472, 474, 476, and 478. Fig. 9D shows a deployable spacer comprising carpenters tape strips 480, 482, 484, and 486 that separate strut members 490, 492, 494, and 496. Fig. 9E shows inflatable sphere 500 separating strands 502, 504, 506, and 508. Fig. 9F shows inflatable bellows 510 separating strands 512, 514, 516, and 518. It will be appreciated that the deployable spacer designs of Figs. 9A-9F may also be used with many different variations on the number of strut members, instead of the four strut members shown in

Figs. 9A-9F. In addition, many different design possibilities for deployable spacers will become apparent to those skilled in the art from the instant disclosure.

Please amend paragraph **[0078]** as follows:

[0078] Figs. 10A-10C show the deployment of strut members separated by the hinged ~~cross brace~~ cross-brace 460 of Fig. 9B. Fig. 10A shows strut members 562, 564, 566, and 568 in a stowed position with hinged ~~cross brace~~ cross-brace 460 collapsed. Fig. 10B shows strut members 562, 564, 566, and 568 in a deployed position with hinged ~~cross brace~~ cross-brace 460 expanded. Fig. 10C is a close up view of leaf catch 569 on hinged ~~cross brace~~ cross-brace 460. Leaf catch 569 secures hinged ~~cross brace~~ cross-brace 460 in the deployed position so that it cannot collapse after deployment, for example from the application of a tensile force to the column assembly.

Please amend paragraph **[0080]** as follows:

[0080] Figs. ~~12A-C~~ 12A-12C show the deployment of column assembly with strut members separated by a hinged/sliding spacer 600, an embodiment of the sprung frame concept of Fig. 9C. This arrangement has several favorable characteristics: it is self-actuated by the coilable deployment kinematics; it stows compactly around the strut members; it is readily reset for repeated stow/retract cycles, facilitating ground testing; and it is readily incorporated into standard designs as an add-on. These are all critical features, and none of the competing concepts that were considered possessed all of these features. Additionally, the practicality of designing, fabricating, and testing this arrangement is clearly greater than a number of alternative deployable spacer designs.

Please amend paragraph **[0081]** as follows:

[0081] The hinged/sliding spacer 600 provides a very compact stowage volume, with springs 620, 622, 624 using the same volume around the strut members or rods 602, 604, 606 as the fixed and sliding fittings. This dimension is key to allowing the column assembly to stow as compactly as allowed by the strut members or rods 602, 604, 606 themselves.

Please amend paragraph **[0082]** as follows:

[0082] Additionally, it was found analytically and by demonstration with the test hardware, that the hinged/sliding spacer 600 is well restrained by the bent condition of the stowed strut members, and that the spreader will deploy by itself as soon as the strut members or rods 602, 604, 606 straighten. This passive method is very attractive for many reasons: it does not require external actuators requiring power or telemetry; the actuation source is distributed, preventing a single failure from affecting other elements; and the spreader springs do not load the structure except directly where the spreading action is occurring. This is not the case for centrally actuated spreaders with control lines running axially along the mast or otherwise through the truss structure.

Please amend paragraph **[0083]** as follows:

[0083] Referring to Fig. 12A, hinged/sliding spacer 600 is shown in a stowed position with collapsed rods 602, 604, and 606. Fig. 12B shows hinged/sliding spacer 600 in ~~mid-deployment.~~ mid-deployment. Hinged/sliding spacer 600 comprises hinged legs 610, 612, and 614 and springs 620, 622, and 624. The first leg 610 of hinged sliding spacer 600 connects rod 602 to rod 604, the second leg 612 connects rod 606 to rod 602, and the third leg 614 connects rod 604 to rod 606. Spring 620 acts on the first leg 610, spring 624 acts on the second leg 612, and spring 622 acts on the third leg 614. Each leg of the hinged/sliding spacer 600 comprises a lower and upper collar 640, 644 a pivot arm 642, and two pivot pins 646, 648. The upper collar 644 of each leg of the hinged/slider spacer is fixed to its respective rod. Lower collar 640 of leg 614 slides over rod 604, upper collar 644 which is fixed to rod 606 through pin connection 650, and pivot arm 642 is connected to the upper collar 644 through pivot pin 648 and connected to the lower collar 640 through pivot pin 646. During deployment, springs 620, 622, and 624 expand forcing the lower collars on the hinged/slider spacer higher up their respective rods. Each lower collar has a fixed tab 632 that mates with a recess 630 on each of the upper collars. Fig. 12B shows fixed tab 632 on lower collar 640 of slider leg 614. Fixed tab 632 mates with recess 630 on the upper collar of leg 610.

Please amend paragraph **[0085]** as follows:

[0085] As noted above, the column assemblies according to the present invention can also be incorporated into coilable trusses to provide them with the benefits of second order augmentation. A preferred configuration of a coilable truss 800 according to the present invention is depicted in Fig. 14. Coilable truss 800 comprises a plurality of column members, including column assemblies 802 and battens 804, connected at their ends at truss nodes 806. Column assemblies 802 comprise a plurality of strut members 810 connected to each other at a first end 812 of the column ~~assemblies~~ assemblies 802 and at a second end 814 of the column ~~assemblies.~~ assemblies 802. In the present embodiment, each column assembly 802 further comprises a deployable spacer 816 connecting the strut members 810 of the column ~~assembly~~ assembly 802 at a location between the first and second ends 812, 814 of the column ~~assembly.~~ assembly 802. However, in other embodiments of a coilable truss according to the present invention, no spacer is used. Preferably, a deployable spacer connects the strut ~~members~~ members 810 near the midpoint between the first and second ends 812 and 814. If more than one deployable spacer 816 is included in each column ~~assembly,~~ assembly 802, they are preferably spaced approximately equally between the first and second ends 812, 814 of the column ~~assembly.~~ assembly 802.

Please amend paragraph **[0086]** as follows:

[0086] Any of the deployable spacers previously described can be used in the column assemblies 802 according to the present embodiment. However, those that are elastically deployed are particularly well suited for the present application. Deployable spacer 816 collapses when the truss assembly is in its collapsed state and expands to a deployed configuration that radially expands the strut members 810 away from the longitudinal centerline of the column ~~assembly~~ assembly 802 when the truss 800 is in its deployed state. Deployable spacers 816 preferably symmetrically arrange their respective strut ~~members~~ members 810 around the centerline of their respective column ~~assembly~~ assembly 802 when truss 800 is in its deployed state.

Please amend paragraph **[0087]** as follows:

[0087] In the present embodiment, column assemblies 802 form three longerons 818 that are arranged parallel to one another and that extend the length of the truss. Further, strut members 810 are continuous members that extend the length of longerons 818. As a result, longerons 818 are jointless and strut members 810 pass between truss nodes 806 between contiguous column assemblies as illustrated in Fig. 15. As also illustrated in Fig. 15, the column ~~assemblies~~ assemblies 802 of the present embodiment each include four strut members 810, but in alternative embodiments, three or more strut members may be employed. Longerons 818 are connected to a pair of end plates (not shown) in manner customary to conventional coilable trusses. Battens 804 brace the three ~~longerons~~ longerons 818 at regular intervals corresponding to the ends of the column assemblies 806 to define a plurality of bays 819 along the length of the truss 800. In alternative embodiments of the invention, battens 804 may be replaced with column assemblies 802 according to the present invention or radial spacers, such as in U.S. Patent No. 4,918,884. Diagonal cable stays 820 are stretched between opposing truss nodes 806 on each face of the bays 819 in a conventional manner.

Please amend paragraph **[0088]** as follows:

[0088] Coilable truss 800 is collapsed and deployed using conventional methods. To collapse truss 800, the ~~longerons~~ longerons 818 are elastically buckled between battens 804 so as to coil the longerons between the endplates (not shown).

Please amend paragraph **[0089]** as follows:

[0089] As illustrated in Fig. 15, coilable longerons 818 ~~is~~ are preferably assembled so that the strut members 810 have a running shallow helical twist along the length of the longeron to prevent detrimental spreading when the ~~longeron~~ longeron 818 is coiled. This spreading, or "brooming" action is the result of the strut ~~members~~ members 810 attempting to all move towards the neutral axis and minimize their axial strain energy. If the strut ~~members~~ members 810 follow a helical path they are not required to strain axially when the ~~longeron~~

longeron 818 is bent or coiled. In other words, by adding an appropriate amount of helical twist along the length of the stranded ~~longeron,~~ longeron 818, each strut ~~member~~ member 810 of the ~~longeron~~ longeron 818 will have the same average or net path length, thereby eliminating or minimizing axial strain.

Please amend paragraph **[0090]** as follows:

[0090] The use of column ~~assemblies~~ assemblies 802 having deployable spacers in a coilable lattice structure allows for the possibility of creating a deployable coilable lattice structure with considerably greater ~~cross section~~ cross-section than conventional coilable trusses would permit. Such a lattice structure can be easily coiled for storage with acceptable strains since the strain is directly related to the diameter of the strut ~~members.~~ members 810. In addition, because the strut members 810 of the column assemblies are of a much smaller diameter than the diameter of the tubes or rods in conventional coilable trusses, the stowed strain energy can be much lower in the coilable trusses of the present invention compared to the stowed strain energy in a conventional coilable truss structure. Alternatively, because stowed strain energy can be significantly reduced by employing the secondary augmentation technique of the present invention, the size of the deployment equipment can be reduced, thereby reducing the parasitic mass associated with the truss ~~structure~~ 800.

Please amend paragraph **[0091]** as follows:

[0091] Fig. 13 illustrates a range of stranding options for strut members of column assemblies according to the present invention. Near the center of Fig. 13 is shown a ~~cross section~~ cross-section of a column, depicted as a circular rod 700, that is to be replaced with a column assembly according to the present invention. Circular rod 700 could also be a tube. Circular rod 700 could be a member of a lattice truss, such as a batten, diagonal or longeron. Referring to Fig. 12, moving vertically up from rod 700, there is a column 705 formed from three circular rods, with the ~~cross sectional~~ cross-sectional area of each of the three rods that comprise column 705 being one third the ~~cross sectional~~ cross-sectional area of circular rod 700. Thus, the sum of the ~~cross sectional~~ cross-sectional area of the three rods of column 705 is the same as

the ~~cross sectional~~ cross-sectional area of circular rod 700. Replacing rod 700 with column 705 is one of the simplest embodiments of a column assembly according to the present invention. Such a replacement is referred to as ~~stranding.~~ "stranding." In a slight variation of this embodiment, the three rods of column 705 could be twisted about their collective centerline to limit brooming as discussed above if used in a coilable truss application.

Please amend paragraph **[0092]** as follows:

[0092] Moving vertically up from column 705 is column 710, an example of stranding with seven rods with constant total ~~cross sectional~~ cross-sectional area. Moving vertically up from column 710 is column 715, an example of stranding with even more rods. Columns 705, 710, and 715 are examples of stranding with constant total ~~cross sectional~~ cross-sectional area.

Please amend paragraph **[0093]** as follows:

[0093] Another stranding option is to replace the original rod with multiple rods where every replacement rod has a ~~cross sectional~~ cross-sectional area equal to the ~~cross sectional~~ cross-sectional area of the original rod. Under this type of stranding, the replacement of a single rod with five rods results in a column structure that has five times the ~~cross sectional~~ cross-sectional area and many times the section inertia of the original rod. Moving vertically down from rod 700 in ~~Fig. 12~~ Fig. 13 are additional examples of this type of stranding. Columns 720, 730, and 740 are examples of stranding with multiple rods where each of the replacement rods have the same area as the original rod.

Please amend paragraph **[0095]** as follows:

[0095] As will be appreciated by those skilled in the art, there are numerous possible configurations for stranding with multiple rods including, without limitation, using replacement rods of unequal ~~cross sectional~~ cross-sectional area, rods of non-uniform shape, unsymmetrical configurations of the replacement rods, and others. Any combination of ~~cross sectional~~ cross-sectional spacing, strand number, and size may be considered when optimizing a design for its particular requirements.

Please amend paragraph **[00101]** as follows:

[00101] However, multiple methods of fusing the strands or strut members of ~~a non-expanded~~ non-expanded column assembly together (after deployment) to obtain more substantial resistance to strand separation (and hence individual buckling) are possible. For example, a rigidizable resin, such as a thermoplastic resin or UV curable resin could be employed in such applications. Preferably, a thermoplastic resin is employed so that deployments of the structure could be repeated on the ground to prove reliability prior to use in orbit.

Please amend paragraph **[00105]** as follows:

[00105] First, a deployable structure can be configured as a lattice structure. Lattice structures are more advantageous than shell structures for several reasons. Shell structures are susceptible to thermal ~~bending~~ bending, which prevents them from being ~~stable highly~~ stable, highly dimensionally ~~accurate structures.~~ accurate structures. Additionally, shell structures cannot be well-optimized for mass given gossamer load conditions. The "optimum" shell wall is too thin to manufacture without imperfections and the column is therefore prone to catastrophic buckling. Lattice structures are not as susceptible to thermal bending as a closed shell, as the sun can shine on structural elements on all sides of the boom at the same time.

Please amend paragraph **[00106]** as follows:

[00106] While variants of the common lattice structure are preferred and well utilized, according to the present ~~invention~~ invention, reformation of the required structure area in the first-order lattice into stranded column assemblies will allow further advantages. One example is tighter stowed ~~packaging:~~ packaging. Open lattice column assemblies can be nested to increase compaction by at least a factor of 4. The basic structural advantages of a lattice over a thin-walled shell are realized again with the secondary latticing. Thus, the realization of higher mass efficiency and compaction benefits are compounded.

Please amend paragraph **[00109]** as follows:

[00109] The second order augmentation technology of the present invention also allows more mass optimum configurations of high performance graphite composite material to be arranged to form stable, low coefficient of thermal expansion (CTE) structures. Numerous low cost methods allow the arrangement of continuous ~~fibers~~ fibers, which are nearly axially oriented for maximum stiffness and minimum CIT. For example, continuous lengths of unidirectional material can be fabricated by pultrusion and then used in short lengths or longer curved sections bonded into segments of articulating column assemblies, or full global column lengths if, for example, it is used in a coilable lattice structure.